GENERAL **ACCOUNT OF ARMY RADAR**
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My first contact with War Research came through Tizard. We met at lunch in the Athenaeum and there he talked to me about new and secret devices we were building to help to shoot enemy planes out of the sky. These devices would be troublesome and would require a team of nurses - would we - the Cavendish - undertake to come in and act as nursemaids, if and when war broke out. He talked also of wanting large powers at short wave lengths and would we think about it. This was in early 1938 - pre Munich. Tizard promised to arrange for us to see these devices - but these were Admiralty inventions and for a while nothing happened. The next move came after the brief scare of Munich - when the Cavendish was to be mobilised to move a mysterious station - later known to have been Bawdsey - from East to West. Fowler now arranged that he and I should visit Bawdsey together and that I should be initiated into Secrets. We motored from Cambridge by Woodbridge across the heath country I was to know so well later. The mysterious towers of Bawdsey rose into the sky and we were admitted to the road through the woods, which led to the fantastic 19th century, manor house used as headquarters of A.M.R.E.

There we met Watson-Watt who produced for us the Child's Guide to R.D.F., used apparently with great effect on Cabinet Ministers. We had explained to us the elements of pulse technique; how to measure direction and height and how R.D.F. was to be fitted to planes to find ships and other planes and to ground stations to shoot guns. We were shown the Bawdsey chain station - with its magnificent 320-foot steel towers for transmitting and its 200-foot wooden towers for receiving.

In a cabin in the field we saw the very first G.L. - being built up by Pollard and Forshaw.

We left thrilled with these first visions of a new war science.

Our next visit was in the spring, the shadow of the Czech disaster over us. I took Dee, Lewis, Ratcliffe, the leaders of the Cavendish. This time we had lectures and all was explained to us at low level by Bowen, Williams; Lardner; Whelpton, old hands of RD.F. Bowen showed us his first air borne transmitters for A.I. and A.S.V. We saw also the station on the cliffs, which was the first of all coast defence stations - Butement in charge.

Following on this visit Watson-Watt came to Cambridge and we discussed with him all the ways we would set to work to fox his baby. We invented toy balloons - to be sent up by the thousand - delayed Pulse oscillators - all the things that we started to use against the enemy in 1943. It was decided after this that we should let Lewis go to Bawdsey to take charge of their research.

The summer went on, the clouds of war threatening. We arranged for a grand introduction of Physicists to RD.F. - a party of eighty to be or organised to spend a month on chain stations, starting on September 1st - a good choice.

A last peacetime visit to Bawdsey culminated in a great cricket match Bawdsey versus Cavendish. I remember Rowe and Larnder playing against us. I scored 30 and we won easily.

August was spent in organisation of the parties. My part was to go to work on Army problems - G.L. at Bawdsey – for Gough had meantime booked me for his work. We had booked a Bungalow on the river - for the family. But the war decided otherwise. I took them hastily north and arranged hurriedly with Watson - Watt to go to Rye instead – for Bawdsey was evacuated on September 1st.

I had with me Oatley, Coemption, Shire, Lathum, Ashtead, Dunworth - a very good party. We sat in the sun at Rye and taking the sacred handbook of C.H. to pieces, learnt our RD.F. chapter by chapter from it

We lived in comfort at Rye and were treated tolerantly by the very able Flight Sergeant in charge of the C.H. Station. We expected to see panes by the thousand - but planes came there none.

We had two weeks of this, I corresponding with the seven other parties distributed round the coast. Ratcliffe ran the Dover party with his usual devastating efficiency. Wilkes was at Faversham, Wynn-Williams at High St - with a London party, Mark Oliphant at Ventnor - on and off rebuilding

the station most of the time; the Clarendon Lab. party rather discontentedly settled near Hurst Monceux; Skinner and Fertel with a Bristol party quite happy at Poling, near Anundal. The Manchester party in Yorkshire were rather isolated and finding little to do broke up in two weeks.

We, from Rye, went back to Bawdsey to study Coast Defence and there met the redoubtable Admiral Sir James Somerville. He turned up one day with a tame submarine with a wireless set to control the same, and proceeded to spot it on the C.D. set. He nearly lost it to one of our bombers but fortunately it survived and he went away full of enthusiasm.

I was then sent for by Watson-Watt and asked if my party could take on the fabricating of three stations - two to be placed on Fair Isle and one on Shetland to ‘close’ the Fair Isle Channel.

Then begun our introduction to RD.F. Development on un-Civil Service lines. We decided to start work at Cambridge. Ratchife was brought in with his party from Dover. He himself drove the first lorry load of materials from the abandoned Bawdsey store to the Cavendish - a transaction, which took three years of war to liquidate. In the high Voltage Laboratory we began to build with aid of Phe’s wiffing team the first “C.D.U.” receivers - U for “U-boats”. Design was based on Butenents Bawdsey C.D.set; development was certainly trial and much error. We were persuaded after a few weeks to move to Christchurch where A.D.E.E. had migrated. There we should have more facilities and more contacts with experienced hands. So, on September, we loaded the Humber and abandoned Cambridge. At Christchurch, Ashtead and Fertel seized on a G.L. Mk. 1 transmitter as a basis for a C.D.U. transmitter. With a hacksaw and a few hand tools, a transmitter was changed to work on 200 megacycles and in very short time we had our first station working.

Meanwhile, Ratcliffe had surveyed Fair Isle with Admiral Sommerville and had made a great impression on that officer - being voted “Worth a guinea a minute”. I recruited at Cambridge G.C. Evans, a Johnian plant physiologist; Douald Carmichael, an anthropologist, and J.A. Lewis, brother of W.B., a civil engineer lately returned from the East. They were put into the RN.V.R, to take charge of the stations and became the first contingent of “Col. Miles private army”- Col. Miles being the Marine officer given charge of the stations.

Skinner and Dunworth went up to Sumburgh Head on Shetland and selected a site close by the lighthouse. Coemption went to Fair Isle where conditions were made more difficult by having to tranship stores from Lerwick by drifter with further transhipment to flip boat on arrival at Fair Isle. The winter was the worst of the war, with high gales and snow. Material for the stations had to be hauled by oxen up a gradient of one in four. Labour was scarce and difficult and we dropped a long way behind our target dates. Sumburgh was on the air by the first week in December 1939. The first Fair Isle station worked by February 16th; the second by February 23rd.

The performance of the stations on submarines was good. Fair Isle detected broadside on submarines at ranges of up to 25 miles. Aircraft were detected at ranges up to 70, miles, and it was very soon found that the greatest use of the stations would be in giving warning of low flying attack on Scapa Flow. For owing to the much shorter wave length (1.5 metres) as compared to the C.H. station at Netherbutton, low flying aircraft were detected at much greater ranges.

Great though the technical difficulties were in keeping the station running they were small compared with the organisation difficulties of getting proper use made of the information. It was too often found that there were no suitable craft to hunt for any Submarines located. On one occasion two destroyers were got out from Rosyth to look for subs. reported round Fair Isle. And in late February 1940, Lewis reported that Lyness (Scapa) was not making use of their aircraft reports in the mistaken impression that they were not accurate enough. By March, however, thanks to Admiral Somerville’s intervention these difficulties had been cleared up and a sound organisation established for passing and using information. The stations then became a major source of information to the Fighter Station at Wick and were often responsible for getting the Hurricanes off the ground to intercept raiders.

So well established did they become that in January 1940, it was decided to erect a fourth station at the most northerly point of the Islands, on Saxavord in Unst. A road had to be made up to the top of a 1000 ft. peak and Lt. Lewis’s previous training was very well used.

In March 1940, Col. Miles and I made a reconnaissance at Scapa Flow and after discussion with the Naval Staff decided to erect three more stations, at Ward Hill, on S. Ronaldsay, at Barebreeke, and on Dunnet Head. These were erected by regular installation units and from this time onwards I dropped gradually out of the Orkney and Shetland picture.

The story of their erection has been written out in detail by Carmichael, Feachem and Coemption. Their account in a fine record of the energy and persistence shown by the party of inexperienced scientists.

Whilst the Shetland erection was proceeding. the first Hitler secret weapon, the magnetic mine, had appeared, and the East Coast of England was getting littered with wrecks. The promise of the C.D.U. station as a detector of low flying aircraft had been recognised. Air Vice Marshall Sir Philip Joubert called me to a meeting with Dr. Watson-Watt in mid-November and asked if my group could take on the erection of two more stations at Foreness Point and at Walton-on-Naze on The Thames Estuary, with supervision of three other stations, at Happisburgh, Spurnhead and Shotton on The East Coast. The dynamic Squadron Leader Gillan was put in charge for Air Ministry Signals and acted as a great expediter throughout the programme, though as he always said, shooting up the Hun was more in his line. Pye's made for us receivers and aerials and turned out at weekends to help to erect. Ashmead went with his hacksaw to Metro-Vick to convert G.L. transmitters and get enthusiastic co-operation - culminating in appreciative verse. Col. Bell, of the Ministry of Supply resignedly and cheerfully produced turntables and Diesels out of his hat. And in no time at all a convoy was on its way from Christchurch through the lanes of Sussex to Foreness Point. There, in a great gale, the Air Ministry erection gang from Kidbrooke, with Shire, put up the first C.H.L, station - the first of the low flying chain, which was soon to spread along the South and East Coasts. Within two days, by December 1st, the station was on the air. Inside its small cabins I saw the first controlled fighter interception made by Squadron Leader Pretty. This technique of single station interception was at that time the subject of hot argument. The Minutes of the Meeting of 19th December at Aerial House provide a record of the arguments put forward by single station and double station enthusiasts. Single station interception won and later developed into the G.C.I. system, which became the key to the night defence of Great Britain.

From Foreness we went to Naze with Ashmead, back from his transmitter work, in charge, From Naze we went to Shotton in Yorkshire with Wilkes. I remember with Gillan arguing on Xmas Eve with the gang of erectors, all equipped with Turkeys and ready for home, that war needs had to take precedence over family reunions in 1939. So the station was on the air by December 27th. from Shotton I went to Spurnhead and waited anxiously for apparatus, finally getting the station going by the New Year.

So it went on through the icy winter. On January 11th, an Air Ministry meeting asked for seven more emergency stations to be erected - Schoolhill, Hill Head, Montrose, Skegness, Flanborough Head, Newbiggin. Bamburgh. From now on however the official Air Ministry organisation began to take over. R.A.E. took an interest in aerials, Kidbrooke in erection and A.M.R.E. (Dundee) in development. On Feb. 12th Shire and I went to Dundee. We were told that we were doing A.M.R.E.'s job. And so we handed over C.H.L. to the care of Ratcliffe, and after defeating an attempt by Rowe to retain my able group, returned to Christchurch to find fresh fields of work.

These stations plotted the tracks of mine laying aircraft and whilst they did not lead at first to destruction of the enemy, they did direct the Naval Minesweeping to the mined Channels. They became a great guide to our own shipping and later as interception technique developed and low flying attack on the country became common they became our second line of Radar Defence.

During this period we had operated from Christchurch as base. I was officially Assistant Director of Scientific Research working with Gough and Paris in London. Actually they were patient and Savoy Hill House saw me rarely. The D.S.R. (Gough) had at this time a very precarious footing in A.D.E.E, which was officially controlled by the president of the R.E. and S. Board, acting under Major General Fullers. The D.S.R. had some ill defined responsibilities for Research as distinct from Development. No-one was quite sure what my standing was but Col Colbeck, the R.E. and S. Board representative most closely concerned was more concerned to help the work than to stand on ceremony and we were given an almost free hand.

Meanwhile the A.D.E.E. was in an embryonic phase. D.H. Black had been appointed Superintendent at the outbreak of war and had gone to Christchurch with the Small Army Radar Team split off from Bawdsey - a team of not more than 20 officers. The Searchlight, Acoustic and Sound Ranging Sections and workshops stayed at Biggin hill till accommodation was more advanced. Forshaw, Young, Pollard and Butement were the senior old hands, with Chick, Oxford and Eastwood, “the three Musketeers”, representative of the bright J.S.O.’s. Oatley set to work to build up the basic group, which was later to become a source of strength to the Establishment. Butement developed, at Steamer Point, a legitimate version of C.D.U., which became known as C.D./C.H.L., a set almost indistinguishable from T.R.E.’s C.H.L., whose development now proceeded at Swanage. From this was branching the more accurate fire control director for Coastal Batteries known an C.D. At the same time Pollard was developing with the Gramophone Co. and Metro. - Vick, the first A.A. fire control set to measure elevation - the G.L.II.

Whilst A.D.E.E, was growing slowly, A.M.R.E. Dundee had moved to Worth Matravers and became T.R.E. Since the Autumn of 1939 it had absorbed the training groups at Dover (Ratcliffe), High Street (Wynn Williams) Poling (Skinner), and had attracted Dee’s party from their P.A.C. rocket inventions at R.A.E., Exeter.

Oliphant’s party returned after a few weeks at Ventnor to Birmingham to work on centimetric valves and reinforced by Sayers from Cambridge, gave birth to the most important Radar invention of the war - the resonator magnetron. My own memories of its origin are not good. The need for high power at the shortest wave length had always been pressed by Tizard. I remember the first magnetron set up on the pump in the laboratory at Birmingham, in February 1940, giving one kilowatt. In May 1940 it appeared in a hut on the Downs at Worth Matravers - a hut which should surely be preserved as the first experimental centre of Centimetric R.D.F. Round this magnetron, precariously waxed to a Diffusion Pump, were the Dee and Skinner teams, Devons, Burcham, Curran, Ward, Atkinson, always furiously engaged in argument, breaking the first ground in centimetres. Crystals were being developed by G.E.C., klystron oscillators by Sutton at Bristol. By July echoes were being received from cars and planes. Centimetres were on the air - and coming into the war, in spite of an important personage who was heard in showing a party round to say that centimetres were for the next war.

Meanwhile since early 1940 I had been pressing on the R.E. Board the desirability of going to shorter wave lengths for accurate fire control. Signal School were building a 50 cm. set - Later to become their *584* set. Shire, Latham and Ashmead set to work to build the first 50 cm. G.L. on the roof of a Steamer Point Hut, and by March 1940 had ranges on aircraft of *5* miles. By June 1940 the set was picking up enemy ship echoes from the Cherbourg Coast - our first continuous experience of anomalous propagation. They modified a Naval *584* set to take split and installed it at Dover, to give the gunners better ranges

By August, however, centimetric applications were in the wind. T.R.E. were working on a centimetric Al. for night interception; I asked Bristol to take on a centimetric searchlight director. Oliphant started to build at Birmingham a rudimentary *7* cm. G.L. using a klystron 10 watt transmitter and two six foot mirrors.

THE TIZARD MISSION

Meantime, in August, I had been commandeered by Tizard to join his Mission to North America to open up exchange of information with the United States. He obtained a blanket authority from the P.M. to disclose anything. Fortified by this we got together the famous “Black Box” collection of samples and reports. At the top of the list was a precious 9.1 cm. magnetron and crystals. Next to it were the micro-pup series of valves which had made our 200 megacycle A.I. and A.S.V. possible. We put in all the reports within our sphere of knowledge, R.D.F., No. 3 predictor, Gyro (type 6) gunsight; rockets, jet propulsion.

The Mission consisted of Tizard, Col. F.C. Wallace - back from Dunkirk - Capt. H.W. Faulkner, R.N., Grp.
Capt. Pearce - from Coastal Command, myself, Fowler, then doing liaison work in Canada, Dean Mackenzie, and Air Vice Marshall Steadman from Canada, and Woodward Nutt as secretary. We left in the Duchess of Richmond on August 31St and sailed in Halifax harbour on September 6th just behind the first of the 50 Lend Lease destroyers.

The Mission was magnificently organised by Tizard. One of his great inspirations had been to bring a mixed team of Serving Officers and Scientists. So our American friends for the first time heard civilians holding forth with authority on instruments of war with their service friends following on with practical experiences.

Our trump card was undoubtedly the magnetron. We produced it at a meeting in The Wardman Park Hotel attended by Admiral Bowen and U.S. Naval Research Laboratory officers. I still remember the rather doubtful opening with the U.S officers suspicious as to whether we were putting all our cards on the table. The disclosure was the key point and from then on we had no difficulties. We found the Navy Lab. had been experimenting with klystron 10 watt transmitters, and were intensely interested. We visited the Bell Labs. on October 3rd and left the magnetron over the weekend with Dr. Kelly. Within three days they had it working and developing power, as Bowen saw on October 8th. We were taken on September 24th to Holmdale where we saw Southworths fundamental work on 10 cm. reception. They also were limited to the 10 watts~ of the klystron. Our disclosures had therefore increased the power available to U.S. technicians by a factor of 1000.

At this time the shortest wave length contemplated for development by U.S. was 50 cms. We saw at Whippany the development of a 50cm. Naval gunnery set, which was later to become their standard S.D. set used in the early Stages of the Pacific War.

Our most important meeting was at an unofficial weekend party on September 28th - 29th in Alfred Loomis’s house at Tuxedo Park. Alfred Loomis was Chairman of the N.D.R.C. Committee on Microwaves. He had collected there a small party of experimenters, including Frank Lewis, who were busy experimenting with Sperry klystrons on 10 cms. They were using Doppler for detection and we saw Cub training planes picked up at 2 miles. The magnetron opened up new vistas to them

We had a memorable session with Loomis, Prof. Eddie Bowles, Frank Lewis; Ernest Lawrence, Bowen and myself. Loomis proposed the founding of a new microwave laboratory, the Radiation laboratory. We discussed its programme and agreed that as night attack was England’s direst peril the first objective should be a centimetric A.I. Bowen sketched the outline of the system and later took a great interest in its development. We suggested a centimetric G.L. equipment - which was later started as the SCR.584. And from the U.S. side came proposals for a long wave pulse navigation system, which later became LORAN. We were slightly embarrassed in these discussions since we had some knowledge of Gee, which Tizard had decided not to disclose since it could easily be countered by jamming. I remember walking round the lake telling Loomis that we had a navigational system, which could not at that time be disclosed. Within a few weeks from this meeting the Radiation Laboratory was in being - a laboratory, which soon rivalled T.R.E. in fertility and drive - a laboratory I was not to see till four years later on the Watt Mission.

Tizard had departed by air on October 2nd, sending me as a parting gift the *5* dollars owing to me on a bet that England would not be invaded by that date. He left me to act as Deputy Chairman of the Mission, with Fowler, Wallace, Bowen and Woodward-Nutt. We continued our visits and on October 27 went to Ottawa where a small party was already at work on 3 metre R.D.F.

We proposed that Canada should take up five new lines. First they should put up a copy of the British A.S.V. into production, using micropup valves. This was later to become the only source of A. S.V. in North America when Pearl Harbour came and the sinking of ships on the East Coast became almost catastrophic. Second, we suggested they take up a centimetric G.L. since at that time blind fire for A.A. had become a major requirement at home. We laid down a specification with a maximum range of 14,000 yards and were heartened by a cable from England quoting the

results obtained on Oliphant's rudimentary G.L. Third, they should cooperate with the Radiation Laboratory on airborne centimetric sets. Fourth, they should cooperate with the Radiation Laboratory on the development of Loran by, putting up one of the ground stations in Nova Scotia; and last, they should develop blind landing systems as part of the Empire Air Training Scheme. The last they did not put into effect.

We visited Northern Electric and arranged for them to take up magnetron and micropup manufacture. And we spend a weekend with Col. Philips discussing a proposal that Research Enterprises should take up manufacture of R.D.F. equipment. Finally, we left behind as a parting loan to Canada, Col. Wallace who since became the head of Research, Development and Production of Canadian Radar. To the United States we bequeathed Bowen who, as much as anyone else, contributed to the early development of centimetres in the Radiation Laboratory. My last job was to compose a memorandum to the Ambassador, Lord Lothian, proposing the Establishment of a Central Scientific Office in Washington to continue the Liaison established by the Tizard Mission. Fowler, then Liaison Officer in Canada, was left to hold the burden, which he did magnificently, till he was relieved by Darwin and Webster, the first Director and Secretary, respectively of B.C. S.O. On December 7th, I sailed for England via Lisbon.

I returned to find England still in the throes of night blitzes. As I passed through Manchester on December 28th, the centre of the city was still burning fiercely; Liverpool had 5 successive nights of terror; London had seen its worst nights but was still and uneasy place in which to sleep.

UNSEEN AA. FIRE

I found that in my absence great effort had been concentrated on to unseen shooting for anti-aircraft. The only, fire control set available in September 1940, was the G.L.I which had no method of measuring elevation. A modification was hastily devised by Mr. Bedford of Cossor, based on the same principle as G.L.II, enabling elevation to be obtained. Modifications were forthwith put in hand to all sets. The army training programme for technical personnel to maintain the G.L's had been far behind requirements. A new school was accordingly set up at Petersham with Ratcliffe, snatched from T.R.E., as Superintendent and Shire as Deputy. Civilian radio officers were recruited in hundreds largely, from biologists and members of the teaching profession. They were put through the school set up in the Petersham Vicarage and Church at a great rate, and set out by A.A. Command to live on gun sites to keep the G.L.'s in order. There were received with enthusiasm by A.A. Command, but not always by the Battery Commander and his staff who thought little of G.I. 's at first. One battery officer told me that he hadn't joined the Army " to become an electrician" - it took a great deal of persistence on the part of Command to break down this attitude and to make Commanders realise that the G.L. was the new eye of the battery.

The G.L.'s were found to be rather temperamental in that calibrations depended on feeder condition and length rather sensitively. Feeders had to be stroked to keep them going. Calibration squads were formed from Radio Officers to operate throughout the Command. Calibration errors of as much as 3 degrees were not unusual but were gradually reduced through the efforts of these squads acting under Ratcliffe's direction.

Additionally to this, Prof. Blackett had been appointed Scientific Adviser to A.A. Command in August 1940, largely through A.V. Hill's initiative. He had gathered round him a small but very, able group including Bayliss, A.H. Huxley, D.K. Hill, A.W. Porter. This group set out to collect reliable data on the effectiveness of A.A. shooting. Battery figures of rounds fired were collected and related to the number of "birds" claimed. Rounds per bird became a measure of the accuracy of our A.A. fire and started at the high figure of 20,000 for the unseen shooting of autumn 1940. Experimental work was initiated to study the response of Vickers and Sperry predictors to the very wobbly unseen date, going in. Predictors had bean designed for visual data only and no one in the predictor world had troubled to investigate what sort of data they were likely, to receive in the future. So Bayliss and his assistants set to work to study the reaction of predictors to unseen data and were driven to suggest the expedient of disconnecting the Sperry rate mechanism, feeding in rates instead from a plotter.

By all these efforts rounds per bird were reduced from 20,000 to 4000 by the spring of 1941, about 100 birds having been claimed by that time. This seemed to be about the limit of G.L.I and corresponded to an average error in future position of about two degrees.

Meanwhile research and development effort had been stimulated to apply centimetres to unseen fire. The 50cm. work at A.D.E.E was stopped and with the backing of the R.D.F. Application Committee of the Scientific Advisory Council a “Joint Establishment Investigation Group” had been formed to build a 9.1cm G.L. a small but able A.D.E.E. team was formed under Pollard, including Ashmead, Latham and Dunworth. Unfortunately an attempt was made to set it up away from the Establishment, at Birmingham, in a barren hut near the Physics Laboratory. For two months little progress was made save in collecting stores and equipment. I attacked the policy of separation on my return from America in December and secured the return of the party to Christchurch with some staff working at B.T.H.

Meantime the high priority given to A.A. defence measures had resulted in both A.S.E. and T.R.E. starting work on the problem. Robinson and Brown at T.R.E. built the first experimental centimetre G.L., which approximated to the final model. It had a pair of three-foot mirrors mounted on top of an old G.L. cabin, the aerials being rotating dipoles giving split with a pip matching display.

Robinson and Brown took their set to Rugby where B.T.H. with the help of Ashmead, Latham and Dunworth, were designing their A model, with little control from the Establishment. They. mounted two four mirrors on a searchlight turntable with transmitter on the mounting and display for bearing and elevation. It was completed in April 1941 and trials were carried out at Christchurch in May and June of that year. They showed that bearing and elevation accuracies of about 10 minutes of arc were attainable by good operators and that the set could follow typical planes out to about 18000 yards. It was shown also that good following down to low angles of elevation could be obtained, whilst there was, of course no difficulty in following planes to the Zenith. The set demonstrated therefore the great advantages of centimetre waves for G.L. It was not, however, engineered for service use, being inadequately waterproofed and not suitable for rough cross country usage. We had, therefore, to insist that a complete redesign was necessary for production equipment. Air Ministry took rather a different view and ordered about 12 equipments with 6 foot mirrors for determining height of planes. They discovered later how unserviceable the equipments were and they were always a full time job for a maintenance crew.

The direction of the work now reverted to A.D.R.D.E. with Shire in charge on his return from Petersham. Discussions on the form of the redesign were unduly prolonged, the war office desiring a two trailer model and A.D.R.D.E. a single unit. The matter was finally settled in July. a large trailer with two four foot mirrors mounted on top, rotating with a large drum inside the cabin, was agreed. B.T.H. were responsible for the design of the transmitter and aerial system and cabin and the Gramophone Company for the receiver and presentation unit. The Gramophone Company sent draughtsmen to work with us at Christchurch and with Shire and Lowther watching their design work, produced a very satisfactory unit. Latham stayed at the B.T.H. to help with the magnetron development; Ashmead worked on aerials and Dunworth on the remainder of the equipment. The War Office ordered *5* pilot “B’ Models. The first of these was delivered in January 1942, and proved to have generally satisfactory performance. It had some unsatisfactory features such as a nutating instead of rotating aerial, a rather unsatisfactory thyratron H.T. supply, and a poor magnetron. The design of these units was therefore changed for the production order, which was not placed until autumn 1942. 1500 sets were ordered, 500 each from B.T.H. Gramophone Co. Metro-Vick / Ferranti and Standard Telephones. The B.T.H. took over a hosiery factory at Leicester for the work of re-equipped it with a fine collection of tools. This, with collection and training of staff, was however, a slow process, and in consequence pre-production models did not come before Spring, 1943, with the full flow of production in August 1943. Of the three years from first experiment to full production, about six months were wasted due to the false start on the A design and about six further months due to indecisions of policy and slow placing of orders. Two years would have been a reasonable time for a job of this magnitude. In the end, the production models proved to be very robust and gave good service. As was inevitable, they were overtaken by the march of technical progress long before their appearance. It was clear enough in May, 1942, (R.D.F. Application Committee 17.6.42) that the operators should be eliminated and automatic following substituted. We worked at low priority on modifications to provide automatic following but against War Office

indifference. By June 1943, the efforts of Robson had produced a satisfactory modification of B. 1 and show that bearing and elevation errors could be reduced from the 15 minutes of hand following to about 6 minutes. We proceeded, again at low priority to engineer this modification but were instructed by War Office that it must be for record purposes only.

Automatic following was, however, sold by the arrival, in September 1943, of one of the first, U.S. autofollowing G.L'S the S.C.R. *584,* which I had asked for and got over on high priority. This set created an immediate good impression, particularly since it arrived in charge of a first rate technical officer, Dr. Davenport, with, an enthusiastic Army Officer, Colonel Warner, to back him up. We were so impressed that I arranged for A.A. Command to do some trials for us at their T. S. 21 trial site at Sheppey. They were greatly impressed by the set and pressed War Office for an order. I got into hot water over this trial for I had neglected to ask for War office authority and Eldridge was very angry indeed. However, it was on the basis of this experience that we were able, on November 11th, to advise that the equipment should be ordered as a supplement to A.D.G.B. defences. At this time the flying bomb menace had become real. During my visit to America with the Watt Mission in November - December, 1943, I discussed the question with Dr. Bush, Chairman of 0.S.R.D. and others and found that they would be sympathetic to use of the equipment with B.T.L. predictors and proximity fuzes against the new targets. We (Col. Fisher of B.A.S. and I) cabled accordingly from America and recommended the requisitioning, of 200 equipments. I followed this up on my return. The War Office was not enthusiastic but General Pile took the matter up with D.C.I.G.S. and Mr. Duncan Sandys joined in support. As a result a very high level request was made and granted for 200 equipments. They arrived with commendable promptitude, were deployed in Kent and Sussex and did great service in the months of June, July and August, the A.A. score rising to over 70 per cent of pilotless planes arriving. This high score was considerably helped by the use of proximity fuzes used for the first time in these engagements.

The G.L.III programme was always difficult politically. Its magnitude made it a target for T.R.E. and Air Ministry attack with high level support from Lord Cherwell. The programme was constantly in danger of being cancelled or cut and finally, in the Autunm of 1943, it was drastically reduced by a half, the Metro-Vick production being completely cancelled.

In parallel with the British programme the Canadian National Research Council and Research Enterprises were building a Canadian model. This was initiated during the visit of the Tizard Mission in October, 1940, when night defence was the first U.K. problem. The Canadians built a model in a rotating cabin and got a first unit over to England in January 1942. Unfortunately, this set went to Petersham for two months operational trials and then to the Canadian Amy for training, rather than to A.D.R.D.E. for detailed technical study and constructive criticism. ADRDE did not receive an equipment Until March 1943, and had then to deal with a number of urgent modifications since at the same time equipment was going to A.A. Command and running, into trouble. We then got over Canadian staff and were able to make emergency modifications. In parallel with our effort A.A. Command ran a black market modification unit of their own and we had considerable trouble in legalising their productions. These difficulties would have been avoided had my request for the first model to go to A.D.R.D.E. not been set aside by the Canadian Army. Colonel Wallace explained to me later that this had been done without his knowledge. In spite of these troubles the Canadian sets did good service and formed the greater part of the centimetre equipment available to A.A. Command in 1943.

CENTIMETRES AND THE SEA

The basic work on centimetres was carried out at T.R.E., Worth Matravers in the summer and autumn of 1940. When I returned from America in December, 1940, I found the brilliant and argumentative Dee, Skinner teams installed in the stables of a Langton Matravers house. Never, I think, has such important work been carried out in such surroundings. In December their 9.1 cm. set fitted with 3 foot mirrors had picked up small ships in Swanage Bay at ranges up to 7 miles. (**Note 2**. Skinner report of 21/12). Thereupon a great campaign was initiated to sell centimetres to the Navy. The approach through the official route fell on unsympathetic ears, but young

Commanders were brought down and enthused with the idea, returned to London to inject the seed at Sea Lord level inside the Admiralty. Landale of Signal School was put to work on the problem and in an incredibly short space of time had designed the famous 271 set, the first centimetre surface vessel search set. The first of these equipments went to sea by the Autumn of 1941 after a great production “tour de force” by Captain Willett of Signal School. This set and its successors have played a foremost part in the U-boat war.

THE CENTIMETRE COASTAL CHAIN

We, Meanwhile, were adapting the same equipment to coastal use. It was clear enough that 200 megacycles was now obsolescent for detection of shipping. Kempton was moved to Steamer Point and borrowed, through the good offices of Captain Willett, one of the early 271 sets. He installed this in a rotating G.L.II cabin with a pair of six foot mirrors on the side, developing thereby the first C.D.MK.IV set. We made arrangements for this set to go for trial to Dover, which was to become an unofficial experimental station for A.D.R.D.E. during the rest of the war. The set moved there in July 1941 and immediately proved of great value. From the 330 foot cliffs it was able to detect large ships at ranges up to 45 miles and to see large shipping leaving Boulogne and track them through the channel. E-boats were detected at ranges, up to 34,000 yards **(note 3)** . The set became of great value in intercepting enemy shipping by M.T.B’s and planes. Air Marshall Sir Philip Joubert, C.-in-C. Coastal Command, asked for retention of the set at Dover and the War Office accepted our suggestion of May 1941 to build six more sets in the shops of A.D.R.D.E. **(note 5)**

On November 12th we were asked to get six additional sets into operation, at Foreness, Newhaven, Beachy, Rame head, Trevose and Happisburgh, by January 1st, 1942. So began the series of A.D.R.D.E. crash programmes which was to continue throughout the war. Captain G.W. Raby, R.E., was then in charge of the shops and loved an urgent programme which made an important contribution to the War. He established a firm reputation for meeting dates.

The 12 A.D.RD.E. CD *Mk* IV sets were followed by *50* built by Metropolitan Vickers. In January, 1942, the inventive Harold Gibson produced a transportable version of the set designed for easy shipment overseas. It consisted of a packing box cum cabin on which was mounted a single 7 foot mirror with very simple turning gear and wave guide feed to 271 set. This set, designated C.D MkV, was rather Woolworth in design but an immediate War Office demand prevented any improvements. The sets were made up quickly with Admiralty radio parts and soon formed a part of the defences of the Mediterranean and other overseas ports.

Our next adventure in the Coastal field was the H.P.T. set we installed on the 700 foot downs at Ventnor. The great height obtainable there had always been a challenge to see shipping at Cherbourg. Cherbourg was well outside optical range but we thought it well worthwhile to put up a high power centimetre station to take advantage of any extra bending of the microwaves on favourable days. We discussed this with Air Marshall Joubert and got his blessing and in October, 1941, D. of Radar, Air ministry, asked for the scheme to go forward. **(note 6)** A concrete building was put up inside the C.H. compound; Kempton, with Rose, built a 400 K.W. centimetre transmitter with rotating spark modulator for Allibone of Metro-Vick. A single 10 ft. mirror with wave guide feed was used to provide as much aerial gain as possible. The building proceeded slowly so we sent first to Ventnor a mobile set with 10 ft. mirror. This gave much trouble with mirror distortions and we were glad to get H.P.T. on the air in April 1942. We learnt from H.P.T. a great deal about anomalous propagation. We got a few days of seeing across the Channel by March. Between April 17th and May 7th, long ranges were obtained for about 25 per cent of the period. This rose to about 60 per cent in June, thereafter falling away again. I was at the station on August 19th, 1942 after the Dieppe raid and was greatly impressed by seeing shipping all the way to Dieppe over 100 miles away. During the summer H.P.T. was able on many occasions to plot enemy shipping off the Cherbourg Peninsular and to assist in their interception by our M.T.B.’s. Normal ranges were 38 miles on M.T.B.’s and 45 miles on destroyers and convoys. The station helped also in the interception of the very low flying aircraft, which attacked our coastal towns during this period. Thus, between July 3rd and July 17th, 1942, 371 aircraft tracks were recorded of which 42 were not seen by any other station on the island. On a number of occasions successful fighter interceptions were made

We had pressed for the erection of more stations of this type and after a struggle the R.D.F. Technical Committee had agreed in November 1941 to the erection of three more stations. The War Office was opposed to our doing anything since they argued it was an Air Ministry and, therefore, T.R.E. responsibility. And Air Ministry, Joubert having left, were lukewarm. We were able to get the work done under the guise of our installing three high power transmitters. And so stations did go up at Beachy, Deerness and Truleigh Hill. They were barely ready when wave hopping attacks came in 1943 and only then did Air Ministry turn on the heat.

Pressure for high power centimetre stations came instead from the Admiralty for convoy protection along the East Coast. In March, 1942, A.D.R.D.E. initiated the design of 200 foot tower stations surmounted by a 10 ft. single mirror fed by wave guide from a 271 MK.IV set below. Our workshop and installation section took on the responsibility for getting 13 of these stations on the air and by mid 1943 these were completed. In addition to this, they fitted high power 271 equipment to Orford Castle, to an existing station at Broadstairs and in other locations. These stations were very successful and many incipient attacks by E boats on our convoys were defeated and driven off. In this way did A.D.RD.E. initiate their second coastal Chain

COAST ARTILLERY FIRE CONTROL

Whilst this development was proceeding, centimetres had been applied to fire control. Since 1940, A.D.R.D.E. had been building a 150cm. set to provide accurate fire control data for coastal batteries. This set was inadequate in range and was apt to have bearing errors due to ground reflections. The 1941 success with centimetres at Dover drove home their great superiority for coastal work. I particular, we showed at Dover that splashes of 6-inch shell could be observed at ranges up to 20,000 yards with 10 to 1 signal noise ratio. We therefore pressed for the conversion of the longer wave sets to 10cms before erection. We had a hard struggle. *A.5,* as usual, wanted to see a set erected at C.A.E.E. and put through a long series of trials before agreeing. And the War Officer were lukewarm, finally, in March 1942, Mr. Duncan Sandys was instrumental in forcing the decision to change to centimetres. Following our previous success at Dover we got agreement to install a converted set at Dover “for experimental purposes” and by June 1942, this was in operation. M.2, as it was called, immediately produced a substantial improvement in shooting. Enemy convoys could now be seen by the fire control set throughout their passage through the Channel. Shell splash of the 9.2” and 15” guns could be observed and fall of shot corrections ordered. Enemy shipping had a hard time in passing the Channel from this time onwards.

Following on this we were responsible for installing five of these C.A. No. l MKII stations in the Dover area.

3 CENTIMETRES AND ‘CHARLIE’

By the time the 10cm. stations were installed at Dover a competitor was already appearing in 3cm. equipment. Since 1942 **(note 7**) it had been realised that for engagement of shipping it was most desirable to show at the fire control station a plan display showing targets and shell splashes. The obvious way to achieve this was to scan the battle area with a very narrow beam. This became practicable with the oncoming of 3 centimetres in late 1941. We obtained the basic equipment from Skinner at T.R.E. Lt Vollum came to us from the U.S. Army Electronics Training Group and was set to work on the problem by Kempton. He built up a 6-ft mirror with wobbling wave guide feed and so produced a scanning beam less than one degree wide. Ashmead’s aerial section improved on this and built a most elegant mirror of 12 foot aperture which could be mounted on the ubiquitous G.L.2 cabin. Vollum, an artist in circuitry, with Farley, produced a beautiful display in which ships and splashes appeared as horizontal lines on a plan display tube showing a battle area of 2000 yards in range and three degrees wide in bearing. Pulse length was 1/10 microsecond giving a range resolution of about 25 yards. “charlie” was completed for trials at Llandudno in March 1943. He at once proved to be satisfactory, giving bearing accuracy of about three minutes and fall of sot of 6” shell out to 25,000 yards. The War Office were impressed and the experimental set went to Dover in July 1943. From this 340 foot site it was found that *15”* shell splashes were seen with signal to noise of 15 db at 34,000 yards; 9” shell splashes with 7db signal

noise at 31,000 yards. The gunners liked the new display and Dover shooting showed a still further improvement. From now on very few enemy ships passed through the Channel on straight courses, the most violent evasive action being taken. The War Office ordered 6 more equipments (C.A. No l 4(x)) from A.D.RD.E. shops. The first of these was delivered by November 1943. The rest were completed by April 1944. Two went to Dover, one to Australia, one to U.S. and two were deployed at Ventnor for the Invasion. I had hoped they might look into "Le Havre" since anamalous propagation seemed quite likely at the time set. Actually weather conditions were against anomalous propagation and they proved of greatest service in recording with precision the numbers and disposition of our returning convoys. As a result a saving of 40 per cent in turn round time was achieved.

A production version of this equipment, C.A.No 1 Mk V, engineered to break down into 200 Lb. units for use in the Pacific war was authorised in October 1943. There was a long delay in settling on a contractor and it was not until early 1944 that B.T.H. started work on the project. The War Office got a target date of December 1944. In order to meet this, A.D.R.D.E. undertook the greater part of the display. Even with this, dates slipped back and March 1945 became the official target.

Meanwhile, the advantages of this display for main armament fire control for the Navy had become apparent. I discussed this with A.S.E. with Blackett and Goodeve in October 1944. A.S.E. were at first inclined to say that the idea was good but that our equipment was useless for their ships and that we must transfer our team to A.S.E. to redesign the equipment if anything was to be done. I left it at this stage when I departed with the Watt Mission for the U.S.A. in November 1943. On my return in late December, I found that no progress had been made and that Headquarters were strongly opposed to our taking on Naval work. The great advantages to our fleet in the Pacific War of 1945 seemed so apparent that I persisted and now got Captain Brooking's whole hearted co-operation and we got down to details of practical design modifications. By April 1944, when I left again for Canada, Admiralty were negotiating with War Office for allocation of some of the first 12 sets to be made by B.T.H. An allocation of set to the Navy was finally made by Chiefs of Staff in the late 1944.

ADVENTURE INTO FIELD ARMY EQU1PMENT

The great success of the 3cm. Fall of shot equipment in showing up shell splashes at sea, suggested that we should see whether bursts of shell on land could be seen. In February 1944, Kempton took the set to Larkhill and got active co-operation form Colonel H.W. Taylor of the School of Artillery. It was quickly found that the set could detect moving vehicles, tanks, etc. at ranges up to 20,000 yards and that *5.5* inch shell bursts could be detected to about 14,000 yards. This at once opened up the prospect of directing accurate shooting onto enemy columns at night and of ranging onto intercepted targets by night. Brigadiers Schonland and Sayer became veiy interested and War Office adopted the set F.A.No. l and authorised an order (Minute of 25.3.44)

Since mid 1943 Elliott and Kempton had been working on the application of Doppler to Radar. Kempton's work, with Walford, had directed itself into the centimetre region and by February 1944 had evolved itself into "watchdog", a quite simple set which whistled when pointed at a moving vehicle. Watchdog showed promise of detecting vehicles to 30,000 yards range. The War Office again showed great interest, christened it F.A. No. 2 and ordered set from Pye's to try in the rapidly moving war.

The third field army venture arose from the great nuisance mortar fire had become in the Italian campaign. Shells had for long been detected by G.L. equipment and it seemed certain that we could pick up mortar shell at some range. Trials with G.L.Ill were carried out at Larkhill and showed that detection was certainly possible to about 5000 yards. The important question was that of display. On the return of Chick form his T.RE. misadventure he was put to work to build a radar mortar detector. It consisted of two inclined 7ft mirrors spinning on a turntable mounted on a half-track vehicle with small cab behind to mount a display in which the tracks produced by the two mirrors would be seen and determine the trajectory. This became F.A. No. 3. Radar for the field army was thus definitely on the march.

THE DIRECTION OF SEARCHLIGHT BY RADAR

From the outbreak of war to mid 1941, sound locators were the only methods of searchlight control in existence or envisaged. The had given good service in the hands of trained searchlight troops but the great dilution of searchlight personnel reduced them to almost complete impotence. During raids searchlight beams waved wildly in the sky but rarely found and held a target.

The initiative to apply Radar to searchlight direction came from three J.S.O's of A.D.E.E., Chick, Eastwood and Oxford, who built, in June 1940, on a searchlight mounting, a 200 megacycle director based on standard A.S.V. equipment. The set had four Yagi receiving aerials, which were switched by a commutator right and left, up and down, and signals compared. A single Yagi aerial served for transmitter; spot presentation was used. The set was not in any sense designed but it worked after a fashion. It was introduced to higher authority and instructions were given to A.D.E.E. shops to build 24 models. Unfortunately, with the threat of increasing night raids the S.L.C. became known to still higher authority. I was summoned with Watson-Watt to see Professor Lindeman in August 1940 and told that 12 equipments must be ready "by the next moon phase". The result of this, communicated to General Fuller, was a scramble to try to put the mandate into effect - with disastrous results on the equipment I was away during that period but on my return was asked by Major General Fuller to visit Christchurch and report on what should be done. The sets at that time were extremely unserviceable owing largely, to their lack of development. They were extremely pervious to water and moisture, exposed as they, were to the elements for 24 hours per day. Their phasing switch, an empirical model of Chick's, was a source of trouble and transmitters were continually failing through faulty valves.

By the time I took over A.D.RD.E. Major and Captain Philips had gone into operation in the Local Searchlight area with a view to applying Elsie and improving her performance. Somehow or other, or through our formation of the O.RG. *they* obtained control over 15 searchlight sites in the Ringwood area. They arranged for S.L.C's to be installed at about *5* of these, - sites and kept them running by A.D.RD.E. shops. This provided us with a great deal of first hand experience of their faults. Experience, which we were able at once translate into modifications. More important still we learnt a great deal about the operational use of searchlights. The official A.A. Command practice at that time, forced upon it by Air vice Marshall Dowding, when he was A.C.C. Fighter Command was to group searchlights in threes at 10,000 yards spacing, the theory being that the reinforcement of beams improved the chances of pickup, Furthermore, the official rules forbade more than three beams engaging a target at any time.

We developed quite opposite views. Believing that the essential point of searchlight procedure was holding by visual aids after pick up and visual hand over from light to light, we spaced our Ringwood lights at 3500 yards with one light in three Radar controlled. The T.F.U. pilots at Hum and the night fighters of Middle Wallop Co-operated in our trials and flew for us night after night. It was shown that with this layout planes could be illuminated for 70 per cent of their passage through the area. Practice interceptions were made and it was considered that a very high percentage of kills could be obtained.

Following on this we tried to get our ideas adopted. We first tried to get War Office agreement to adapt control pillars for visual take over. This was discussed at a meeting at A.D.RD.E. and the suggestion firmly turned down. We tried to persuade A.A. Command to change their searchlight spacing. Here we ran up against a typical administrative difficulty. Permanent camps had been built at 10,000 yards spacing and to change to 3500 spacing would throw an enormous burden on the administration since some 6000 sites were involved. Furthermore A.A. command raised the difficulty that they would not have enough troops to go round on the small spacing.

I think that we failed diplomatically and that more skill in negotiation would have won the day, for by late 1943 A.A. Command came round completely to the 3500 yard spacing. At that time they compromised on a 6000 yard spacing. They were with us, however, on the question of control pillars and after a year of struggle the verdict was revised by a Duncan Sandys meeting at the War Office.

The S.L.C. programme, meantime, went on its way to a total of some 3000 sets. The reliability of the sets was steadily improved but at no time was it a fully satisfactory equipment. Resulting from the circumstances of its birth and hurried upbringing the whole system was full of mismatches, with a result that angular errors were larger than need have been. In spite of this, by 1943 good illuminations of enemy planes were once more being obtained in Kent, Sussex; London and East Anglia.

We were asked in January 1942 to submit proposals for a complete redesign of S.L.C. equipment This we did in February, 1942, suggesting that we should aim at greater immunity from jamming, economy in personnel, greater target discrimination, more accurate following and ability, to pick up and follow low flying targets. In May 1942, War Office agreed that we should redesign on a centimetre wavelength. We were not able, however, to begin work seriously until Oxford became free in October 1942. He then began work on an automatic following equipment using a single 4-ft. mirror mounted on the searchlight itself. The modulator was adapted from the L.W. set and T.RE. radio frequency parts were taken over. By the end of March 1943, design information began to be passed to Messrs. Cossor who had been selected for development. A.D.RD.E., meanwhile, continued with the development of their experimental model and by the end of 1943 very satisfactory night runs were being obtained using automatic following.

During the latter part of 1943 “Window’ was used by the enemy in raids over S.E. England and this affected 200 megacycle equipment quite seriously, This brought increased attention to the merits of centrimetric equipment and in February, 1944, we were asked to take on a crash program for S.L.C.S(X) as it was called. We agreed that Cossor’s should not be disturbed in their programme, which was just about to produce its first model, but that, in addition, we should ask Pye’s to build 24 sets. They got to work in great style and by July had their first model assembled.

The part played by S,L.C. controlled searchlights in the war is very difficult to assess. We had many fragmentary reports showing that they had good success overseas, as an aid to fighter Interception, particularly in Malta and N. Africa They were at all times supplementary to G.C.I. control with A.I. as an aid to final interception. And since control of searchlights in U.K. was always in the hands of the RA.F. there was, in many sectors, a tendency to treat searchlight interception as a rather poor alternative to G.C.I. The situation changed somewhat towards the end of 1943 as G.C.I got into trouble with Window. Searchlights were less affected and frequently became the only method of control, and good results were reported. They are, of course, limited to operation on reasonable, clear nights but were nevertheless able to function on a high proportion of raid nights.

With the limited knowledge of operations available at present it seems rather doubtfiul whether searchlights have a future.

THE LIGHT WARNING SET

The need for portable warning sets in the field was first experienced by the RA.F. and T.RE. had, in 1941, built a number of pack sets using standard A.S.V. radio parts, on light wigwam framework and a simple Yagi array to give some directivity. These sets were used in the Middle East. They gave a range of 15-20 miles on aircraft at 10,000 feet.

An Air Ministry meeting held on October 28th, 1941, laid down a specification for an improved light warning set. A.5 and Home Forces had shown some interest in an Army application and on 4.12.41 a C.T.E. (R.D.F. Technical Committee) meeting decided that A.D.RD.E. should be responsible for development work.

After a month’s preliminary work a meeting was held at Bure Homage on 6.1.42 with Air Commodore Leedham (D.R.P., M.A.P.) and it was agreed to place development work for the transmitter and aerials with Metropolitan Vickers. T.RE. undertook responsibility for the development of a nine-inch P.P.I. Designs for turning gear and aerials were largely taken over from T.R.E.

We had Instructions to get 50 sets into the field by the summer if possible, with 400 sets at the end of the year. An A.D.RD.E. set was working at Sopley on March 9th, 1942. Contracts with Metro-Vick were delayed and not placed till February *25th.* Transmitter design was cleared by April *5th.* Trials of the first A.D.R.D.E. set were completed by May 1st, at which time the set was removed for an urgent operational role.

The range of the equipment on aircraft at 10,000 feet proved to be about 40 miles. Rough height finding was possible by comparison of signals from two Yagi aerials at different heights. Two forms of the set were built, ones in a metal frame tent structure and a second mounted in a *15* cwt. army signals truck. The latter proved to be much more popular.

By June 1st A.D.RD.E. completed their second set and this was despatched on June 2nd, complete with U.S. officer to the United States by air, to serve as a prototype for sets to be built there. We heard later that Research Enterprises were asked to build about 50 sets - non-tropicalised - for urgent use. Some of these sets got to North Africa and to the Pacific and gave serious trouble, giving the L.W. set a bad name.

Meanwhile, production did not meet the dates demanded. Three months were required to obtain components and by the end of March promises for first transmitter deliveries were August 1st.

By the end of November 1942, 13 sets had been delivered by, the manufacturer, additional to the 6 built by A.D.RD.E. By early March 1943, 100 equipments had reached the Air Ministry No.4 Maintenance Unit

The sets were used in Montgomery’s campaign from Alamein to Tunisia and in the African landings. We had little news of their operational use but heard a good deal about minor technical troubles, which developed. These were largely due to breakdown of a filament transformer due to transmitter transients. Some trouble was also experienced with the engine generator due to early valve burn out when using Leaded petrol.

The light warning, set was also applied by, A.A. Command to providing, early warning information. A.A. sites for putting G.L.III’s on to target This was forced upon A.A. Command by the shortage of G.L.ll equipment consequent on transfer to Russia, the original plan being to use G.L.ll for “putting -on”. By the time the sets were issued in numbers in the autumn of 1943, Window was being used by enemy planes to mask raids and L.W. sets were seriously affected. A.A. Command lost any enthusiasm they had had for their use and turned to development of drill for self-putting on of G.L.III. LW. set suffered from its almost complete lack of development and it was unfortunate that as may as 2000 sets of the original design were ordered. The advantages of a mobile warning set for the field were however well established. The L.W. sets formed an essential part of the M.A.RU. units established for all combined operations and particularly for the Normandy invasion. The L.W.’s were got ashore almost with the first wave and pushed forward as rapidly as possible, to give the maximum warning of air attack on beachheads. As the beachhead developed, heavier sets were brought ashore to extend the range of coverage.

The U.S. Army and Navy recognised the importance of this type of set. The U.S. Army built models of three types of sets, the S.C.R 602 T.1, T.8, T.7, operating on 1200, 600 and 400 megacycles respectively. The U.S. Navy developed other sets for use by their Marine Corps and when the Watt Mission visited U.S. in November 1943 the tactical role of the set in the forthcoming Pacific operations had been clearly recognised. The existence of the U.S. sets was a deterrent to our taking up any new development of L.W. sets in the U.K. We did modify a number of the 212 megacycle sets to operate on 600 megacycles as a safeguard against jamming in the Normandy landings. And in June 1944, we began the development of a centimetre “very light warning set” for possible use in the Pacific

TACTICAL CONTROL SETS

The need for an equipment designed for the tactical control of A.A. guns was put forward by A.5 as early as October 1941. Butement had proposed the use of a centimetre scanning set (PH) in late 1940. Owing to shortage of manpower it was not possible to do any work on the project until July

1942. Then lager built a set having two six of four-foot mirrors, rotatable at speed up to 20 r.p.m. with a power of about 200 kilowatts. By April 1943, adequate ranges had been obtained and the work was written up. In July 1943 the project was formally added to our programme. But we were unable to obtain the agreement of the War Officer to this design. In January 1944, the War Officer asked us to consider the adoption of the Air Ministry Type 14 Mk.ll set. This was essentially the Naval Centimetre 274 equipment mounted in a G.L.ll cabin, with a 15-foot cheese aerial. We had some fears that clutter would be troublesome but a rapid trial at Earls Croome showed that this was not serious and that ranges of up to 60 miles could be obtained.

On February 21st we offered to adapt 10 to 12 equipments in A.D.RD.E. shops and to complete them within two weeks of the arrival of sets and cabins at Malvern. We knew that they were required for the Normandy invasion and with a great effort the Workshops completed 12 set in time for shipment on D Day and following days. They were got ashore without trouble and we heard form the War Officer that they gave excellent service, being frequently the only warning equipment available.

This equipment gives adequate warning of planes approaching at all heights up to 20,000 feet. It does not give any indication of height and falls sort therefore of one major tactical control set requirement.

The development of a tactical control set making use of scanning beam was, however, firmly turned down by War Office. Instead they decided to adapt the A.F.1 equipment as a tactical control set. We stated on 21.7.44 that its range was not likely to exceed 35,000 yards on a medium bomber and that this was inadequate for tactical control. But in this matter headquarters and War Officer were against us and 300 A.F. equipments were ordered for the putter on! tactical control role.

It seems probable, therefore, that he development of a set for tactical control of large G.D.A'S will be left for the post war programme.

AIDE TO LIGHT ANTI-AIRCRAFT G.R

The development of the 6 pdr. anti-aircraft gun for ranges intermediate between the Bofors and 3.7" gun necessarily required the provision of a radar rangefinder. A decision was taken to use the Naval intermediate role predictor and we were asked in May 1942 to design a radar range finder to "button on" to this predictor, then largely designed.

We recommended that the development should proceed on a wavelength of 25cms. We were led to do this by a staff requirement for a very short starting time when we then believed to be unobtainable with magnetrons. We had already co-operated with the G.E.C. on the development of 25 cms. and we believed that development time of the equipment would be shorter, apart form this, lOcms. would have had many advantages and we can now see that the adoption of *25* cms. was a mistake.

The development proceeded in close collaboration with the G.E.C. and every effort was made to see that development was suited *to* the most severe tropical conditions. The radio units were housed n tow sealed sheet iron boxes and an internal circulation of air was arranged to provide adequate cooling. In spite of every effort to cut down development time, difficulties in obtaining components were such that the first works pilot model did not reach A.D.RD.E. till November 1942. To this A.D.RD.E. fitted the range unit and intensive trials were carried out. Faults were cleared and by May 1943 all engineering details of the production models had been cleared. Construction of these had proceeded in parallel and the first tow works prototypes were delivered to us in October 1943.

The equipments had a range of 10,000 to 12,000 yards o medium aircraft. The proved to be satisfactorily rugged in bump and blast trials and, in general, met the G.S. specification.

The production equipments were used for the first time during the V.1 battles *of* the summer of 1944. I have no record of their performance.

RANGE FINDER FOR BOFORS

The No. 3 predictor used with the Bofors obtained range from observation *of* tracer. Accurate laying ensures that the shell cross the line of sight to the target and a good No. 1 can judge whether range in short or long by observing whether tracers cross in front of or behind the target.

With first class nos.1 and good layers a very high percentage of hits can be secured - up to 15 per cent. Actually, rounds per bird for Bofors engaged worked out to between 200 and 1000. The very elegant system of tracer ranging broke down in the hands of the poor material available to AA command. A demand arose, therefore, from A.A. Command, for another method of ranging. Trials were carried out at Manorbier using the G.R rangefinder to provide range to the Bofors and showed that with target speeds there obtainable, an advantage of three to four was obtained.

We therefore asked authority on 28.7.43 to build two experimental units (R.O.3) For these we used as far as possible standard Air Ministry Radar boxes. The first model was built by the end of 1943 and was sent to A.A. Command for trials in Februaiy 1944.

No official interest was shown in the equipment until the pilotless aircraft attacks developed in June-July 1944. One of my first actions on returning from Canada in late June was to propose that we should build 24 equipments in the A.D.RD.E. Shops. This was accepted and A.A. Command agreed that each one would be used with a battery of 4 guns. The workshop did a magnificent job and the first of the equipments was built by mid July and the whole of August 8th A.A. command reported very favourably on the performance of the equipments during August 1944- the last phase of the main V.1 attach. We have, however, no quantitative figures on performance.

AUTOMATIC BOFORS

Increasing target speeds made it clear that fully automatic L.A.A. equipment would be required in the future and A.D.RD.E. put forward proposals for work in 1943. This was formally added to our programme in January 1944, with the proviso that it should be carried out in collaboration with A.F.E. By May it was agreed that the design should be applied to the single barrel 6 pdr. equipment then being designed.

A more urgent programme was initiated, however, by the success of pilotless aircraft in June - July 1944, and the collaboration of the B.R.H. was obtained to adapt their A. 1(x) -3 cm. equipment, to this role. The defeat of the V.1 attack came, however, before the first equipments were obtained and a most interesting experiment was thereby postponed.

PROXIMITY FUZES

The first incentive to the development of proximity fuzes came during discussions with P.D.E. in April 1940 on proposals put forward by Professor Lindemann to build a “Spaniel” U.P. which would chase an aircraft and direct itself to the target These proposals were shown to be impracticable with the 3” U.P. since the necessary control surfaces would reduce the speed too much. During the discussions between Shire, Butement, Cook, others, and myself the suggestion of using a proximity fuze working on the Doppler reflections from the plane was put forward.

The matter received a further impetus by an investigation of German diodes, which were dropped in bombs. They seemed to me to be very rugged and I took one at Cambridge to spin it in a centrifuge at the Biochemistry Laboratory. I found that it would withstand and acceleration of

about 10,000g. Thereafter it seemed possible that suitable rugged valves could be built. I discussed this with Messrs. Pye who began work on valve development.

Meanwhile, my visit to America with the Tizard Mission led to discussions with Tuve. Tuve was then working on photoelectric and other proximity fuzes. He was already carrying out vertical firing of valves in a small brass cannon to test for ruggedness. We discussed our problems at great length and he agreed to include work on the development of a radio proximity fuze suitable for the British 3.7” gun.

Work in England began seriously in September 1941, in collaboration with Messrs. Pye and G.E.C. Two lines were followed. First, an attempt was made to build a fuze to be operated by a radio pulse from the ground when a Radar set showed coincidence of signals form shell and target plane. This line, know as RO.F. was followed to a demonstration by Messrs. Pye in March 1942, when a good percentage of rounds were successfully pulsed.

Professor Ellis took over direction of the group in January 1942. He carried out a theoretical investigation which showed that the maximum gain achievable by the so-called RO.F. was 2.4 and that the actual gain would probably be appreciably less. It seemed, therefore, more profitable to concentrate work on the true proximity fuze and RO.F. was dropped in March 1942.

Professor Ellis then considered that it would be possible to give an answer as to whether proximity fuzes were advantageous and practicable by the end of 1942. The design of the first, X.3, fuze was developed round the 16mm. diameter valve which G.E.C. Wembley were developing. We had samples of American 10mm. Valves and would have much preferred these. At that time, however, the G.E.C. were not prepared to work at the smaller diameter. An unfortunate result of this was, that the overall fuze diameter was substantially increased over what was achieved by Tuve with 10 mm. valves.

The fuze was developed to use a dry battery of the so-called layer type. This had been built in U.S. by the National Carbon Company and it was natural to bring in their associated company, Ever Ready, to build batteries in the U.K. Their development was, however most unsatisfactory. They wasted a great deal of time in attempting to extract information from the National Carbon Company. Every conceivable obstacle was put in the way of passing over information. Even drawings were refused on the grounds that this would interfere with production. This was due in part to the attitude of one senior U.S. Naval Officer and second to a feeling in U.S. that we were attempting to get information useful in post war commercial work.

Work at A.D.RD.E. in 1942 was slowed up by the move to Malvern.

Much effort was also devoted to establishing the technique of vertical firing for recovery of components fired in shell. We obtained the use of Cleeve Common and were able to do successful firings with a 3-inch gun. Later on a new range was opened at Beckhampton and proved to be useful for trials on mechanical fuzes and condenser fuzes as well as our fuzes.

We also established a range for sea trials of fuzes at Ynys Las.

The American development was, however, making much more rapid Progress. They had a group of over 200 scientists and engineers working on the development together with enormous factory development facilities at Sylvania, National Carbon and other firms. During this period they developed from a Canadian Suggestion (from Pitt’s group) a so-called reserve battery in which an ampoule of electrolyte is broken by the shock of discharge and activates the battery. This promise of a battery with an indefinite shelf life was a great attraction to the Navy. By October 1942 they felt they were assured of a supply of American Fuzes and that the British Programme should henceforth concentrate on a longer-term fuze, which would fulfil all their requirements.

So on 26. l0.42 it was agreed that he British valve manufacturers should be asked to change their design of valve to 10mm. diameter and that an *X.5* fuze incorporating this valve and a reserve battery should be developed for service use. Until the reserve battery could be developed the X.3 and a later X.4 fuze could go on for experimental purpose.

At this stage we pressed that the new 10mm. valve should be identical in characteristics with the American. Unfortunately the valve manufacturers would not develop the U.S. design of filament and their valve had, from the first, a larger battery drain. This prevented us from using the U.S. reserve battery when our own battery development went so slowly.

Meanwhile, by February 1943, the first 500 of the X.3 fuzes had been received and 10 shoots had been carried out at Ynys Las and a large number of listening shoots at Beckhampton. From now on the experimental work was concerned largely to determine the causes of early bursts of the fuzes. A good deal of the early troubles came from a pyrotechnic delay switch, which prevented premature arming. By June 1943, however, we were getting correct operation of the fuzes against gliders suspended from balloons.

Meanwhile we had kept in closest touch with the U.S. fuze development by seconding Thomson to Tuve's group, realising that we had to rely on U.S. fuzes for the first Naval use. In June 1943 Thomson came over with Salant, the representative of Tuve's group most concerned with British requirements, and we were informed that the production position of the U.S. Mark 32 and 33 fuzes was such that there would be no difficulty in meeting the full British Naval Demands. It was evident that the effectiveness of the fuzes might be reduced owing to the much lower fragment velocity of the British shell - owing to their too heavy heavy walls. Also that there might be some difficulties due to the different loading of British Shell.

It was therefore agreed that the first priority of A.D.RD.E. work should be directed to giving assistance in detailed trials of U.S. fuzes and in studying modifications necessary. We detailed Thomson and a small group for this work and trial facilities were rapidly setup by the Admiralty at Shoeburyness. The trials took place against a glider in the autumn of 1943 with satisfactory results and the Admiralty placed extensive orders for the U.S. Mark 32 and 33 fuzes, and fuzes went into operational use in the British Navy towards the end of 1943.

The remainder of the story of fuze development at A.D.RD.E. is of a continual struggle to overcome the disabilities due to poor industrial development facilities. Professor Melville was brought in to lead the fuze group in September 1943, and devoted most of his attention to the reserve battery development. Professor Wynn-Jones of Dundee studied the electrochemistry systems and co-operated with Burndepts at Dundee in applying it to a practical battery. The main Bunidept asset was the enthusiasm of their Director, Mr. Richardson, but they had no technical staff that counted and progress was correspondingly slow. By April 1944, we were still now within sight of a satisfactory reserve battery. We had, however, the limited satisfaction of firings *X.5* fuzes with American reserve batteries and obtaining about 40 per cent satisfactory operation. We had traced down a lot of our earlier troubles to inadequate rigidity in the plastic nose of the fuze and to microphony in valves.

During September, 1943, a diversion of fuze development to a field army requirement was produced by D.R.A.'s request that we should consider the application to air bursting field artillery shell, since air burst at heights between 40 and 20 feet gave a greater fragment effect than ground bursts against troops in slit trenches.

This was looked into and seen to be possible and was at once discussed with the Americans who had, in fact, been experimenting on these lines for some time. Arrangements were at once made with them for the adaptation of a fuze to meet the Army requirements, though a caveat was placed on its field use until release of the Combined Chiefs of Staff was given.

During October 1943, the intettigence reports coming to a Duncan Sandys committee showed that Britain might soon expect a new form of attack - by rockets and pilotless aircraft.

This raised again the question of obtaining proximity fuzes for use by A.A command. I discussed the matter with A.O.R G and they put forward an assessment of the advantages of proximity fuzes when used with G.L. III and SCR *584* Radar. As a result of this, A.A. Command pressed for the allocation of SCR 584 sets with B.T.L. predictors and proximity fuzes. I was able to discuss this with British Army Staff Washington, during my visit with the Watt Mission in November - December 1944 and a joint cable was sent recommending application for SCR584 sets and fuzes. This was

taken up and pressed on my return. I did not get too much sympathy, from the War Office by General Pile took the matter directly to D.C.I.G.S. and a top level request was made for the equipment.

It arrived in time for the height of the V.1 battle and the results of August 944 in which 60 percent of pilotless aircraft were shot down was materially helped by the proximity fuzes used.

We may therefore say that we achieved our operational requirements through our keeping in continuous touch with U.S. development and that this alone justified the existence of the A.D.RD.E. group.

We have less cause for satisfaction on the technical side and the proximity fuze development was A.D.RD.E.'s greatest disappointment. It was due In part to indifferent leadership of the group, but even more to the poor industrial facilities available.

We suffered also from being continuously outpaced by the American development. We realised all the time that our needs would be largely met by America and yet we could not drop our work because of need to develop the technique in U.K. for post war development and to have available a body of technical experience to assist the services. Morale was always difficult to maintain, but in the circumstances we did the best possible.

THE ORIGIN OF A.O.R.G

One of my first objectives on, taking over in April 1941, was to bring the Establishment into closer touch with operations. I had up till then kept in constant touch with A.A. Command through Blackett's research group. About this time Blackett was moved to Coastal Command to become Scientific Adviser to Joubart. He suggested that I should take over his duties as Scientific Advisor to A.A. Command. We discussed this with General Pile, C. in C. A.A. Command, one of the most devoted employers of scientists in this war. It was agreed that I could not combine the duties of Scientific Advisor with those of C.S./A.D.RD.E. but, that we should form an Operation Research Group to be under my direction, The nucleus of the group would be Blackett's A.A. Command Research Group together with a large number of the A.A. command Radio Officers, mainly biologists, whom RE.M.E. did not wish to incorporate in their organisation. Ratcliffe agreed to be Superintendent of the Group and to combine it with his duties as Superintendent of the Radio School, Petershamn. These discussions were followed by Official Meetings at which the War Office agreed to the Scheme.

The organisation was set up by Ratcliffe who remained as Superintendent for three months, when his old ties recalled him to T.RE. I was very fortunate then in being able to persuade Schonland, then over on a liaison visit from S. Africa, to take charge of the Group.

O.R.G. as it was first called took over the problems of the A.A. Command Research Group. They studied the poor response of the Sperry and Vickers Predictors to the wobbly data produced by G.L.I. sets. They were much concerned with the calibration of G.L'S in the filed and with the reasons for wandering of calibrations - due largely to feeder troubles. They took over the analysis of enemy casualties in relation to rounds fired. They started to collect data on the tracks of enemy aircraft. And from this it was logical step to record the G.L. co-ordinates of aircraft and the gun position data during an engagement To do this we introduced recording vans fitted with photographic equipment to record positions of six magslips dials connected to the G.L. magslips and predictor output magslips. From the records taken during the engagements it was possible to plot the G.L. track of the aircraft and the position at which the burst should have occurred in relation to the track. The results showed that bursts were very often over 1000 yards from the target and a good average for G.L.ll would be 400 yards. The figures came as rather a shock to both scientists responsible for design and to A.A. Command.

The data was always studied with great care by A.A. Command. They were able to discover many errors of drill and to correct them and they became a great incentive to further training. One of the great virtues of General Pile was that he always simulated rather than depressed by such information. The scientists in turn learnt that the performance of their equipment nearly always

deteriorated by a factor of two to four in the hands of troops. A.G.L.II might have an error of 20 minutes in the hands *of a* first class operator but might deteriorate to two degrees in the hands of the worst operators. This knowledge was a powerful stimulus to us to work towards a completely automatic system – automatic following G.L., data fed automatically to the predictor and no predictor operators. The Americans achieved this with their S.C.R *584* and B.T.L. predictor. Our records show a continuous struggle to get acceptance of this policy by the War Office owing to some extent to the control of production facilities by M.A.P. It was not completely accepted till 1944.

O.R.G. next extended their activities to the Coast. The brothers Varley were recruited and sent to keep watch on the performance of Kempton's first centrimetric C.D. set sent to Dover. Their activities spread to Ventnor when we installed the high power centimetre set to reach out towards Cherbourg. As we installed the Eastern chain of centimetre stations they were joined by Lack, the bird watching enthusiast. When our centimetre fire control made cross channel engagements profitable, Capt. Varley was there to record and help. Throughout this phase of the war the efficiency of the coastal station must have been almost doubled by their watchful presence.

Their next extension was to Signals when I took charge of S.E.E. for a time in May 1942. Scholand formed O.RS.3, and proceeded to study signals in the field. The O.RS.3, with Ede and Gifi as their senior officers, soon had some success to their credit. Fifi produced and extremely simple system of guiding tanks infantry by defining a Lorent, beam system with ground aerials and using the 38 set as a receiver. They fought a great battle for higher frequencies for forward area sets but lost against strong opposition from the War Office. The experience in Normandy showed how right they were.

About the same time O.RS 4 was formed, to study tank warfare, and were fortunate in taking over Solandt and much of the experience of the Medical Research Council unit at Lulworth. By the end of the year, O.R.G. were spreading more and more fields, which were no concern of A.D.RD.E. Darwin and Ellis, then appointed Scientific Adviser and Deputy S.A. to the War Office, were anxious to take over. And so I relinquished by Very general direction of O.R.G. and its control became vested in a Committee of Darwin, Ellis, Paris and Schonland. The real direction, as hitherto came form Schonland and I was able to continue my interest undiminished, a special feature during this period was a series of Saturday morning discussions on operational technical matters. Amongst these I remember a conference on problems of the Pacific War, at which Tizard, newly returned form Australia spoke, a conference on the possible uses of Radar for the Field Army, at which Kempton presented a paper (appendix **note 8**). only by such close contact can a Design Establishment keep sufficiently close to operations to foresee the needs of the Army a year ahead - as they must in war.

ORGANISATION OF A.D.RD.E.

The organisation of A.D.RD.E. was steadily improved during the war as its staff, recruited largely from the Universities, grew into the work.

Oatley developed a good basic section, which in the end designed first class aerial systems, receivers and transmitters. Their high watermark was reached in the Shell Splash Set - C.A. No 1 Mk.V - where all the basic design was done within the Establishment

We had application groups for G.L. (Friend), Light A.A. (Shire). Searchlights and Light Warning Sets (Chivers), Proximity Fuzes (Rothwell).

Colonel Raby was responsible for building up a very fine workshop organisation totalling about 400 staff The Workshop took on during the war crash programmes for S.L.C., for 10cm. C.A. and C.D. the centimetre East Coast Chain, the 12 Gorgonzolas - or centimetre tactical control sets built for the Normandy landings - and the shell splash sets. The workshop was never large enough but always met its dates.

Administration was in the capable hands of Colonel C.H.S. Evans. We had a difficult time in moving to Malvern and the fight to improve living conditions and amenities had to be continuous. Living conditions were steadily improved and Colonel Evans deserves great credit for this.

The Establishment was weakest in mechanical design. There appears to be a tradition in Government Establishments, which discourages the recruitment of senior design engineers under whom the drawing office should work. We did our best to consult A.RL. but consultants in another establishment are no substitute for good designers responsible for the job.

Our military advisers were primarily the D. of A's branch, A.5 under colonel Paterson.

Our relations with them were always good and their officers were of high quality, had they been a branch of the War Office with executive authority, a great deal of time would have been saved.

Our relations with the War Office suffered from too many links between us, and from lack of technical staff in the War office branches. This led to many delays in obtaining policy decisions.

Production was in the hands of M.A.P. throughout the war. Whilst our own M.A.P. officers did their best for us, the production facilities were at the disposal of M.A.P. first and the Ministry of Supply last. This arose largely from the Directive giving overriding priorities to equipment for strategic bombing.

EPILOGUE

Since September 1939, A.D.RD.E. has mad a continuous contribution to European Victory.

Within the first few months of war we flung round the South East Coasts the chain of C.H.L. stations which was first an aim of the defence against magnetic mines and second, a shield against low flying attack.

We built next a chain of centimetre coastal stations starting from Dover, thence to Ventnor and then up the East Coast. These stations became a great weapon of offense against all enemy shipping passing through the channel, an essential protection against E-boast attack on our coastal convoys, and a defence against wave skimming air attack

These stations spread overseas and we have had testimony to the large amount of shipping they saved.

The A.A. guns were a last line of defence to the cities of Britain. Our G.L. sets provided what eyes the guns had in the night blitzes of 1940. our initial performance was poor but was continuously improved until the advent of centimetres and automatic following showed that Radar controlled shooting could equal visual accuracy. The final triumph of Radar came with the defeat of V.1. attacks in August 1944.

For the field army we provided the Light Warning set which played an important role in amphibious operations and which was the forerunner of many sets with similar tactical role produced by our U.S. Allies.

During 1944 and 1945 we extended the field army application of Radar. Our G.L. sets were adapted to Mortar location and other sets for mortar location were built. We found means of detecting vehicle movements and shell burst which might have found important applications in the Field Army had the war lasted longer.

We began to apply Radar to Light A.A. in the V.1 blitzes of 1944.

The work went far enough to show that Light A.A. must, in future, be Radar controlled.

Our development of X band short pulses systems produced a shell splash set, which was better for Naval fire control than any U.S. or British Naval set.

Our major contributions were therefore to the Air and Sea War. The application to Land Warfare awaited the short pulse, narrow beam techniques, which took long to develop and are only now coming to fruition.

J.D. COCKCROFT JULY 1945.

Note 1. (Extract from minutes of the twenty - sixth meeting of the RD.F. Application Committee

June 17th 1942.

318. Automatic Following.

Mr Huxley summarised the operational advantages of automatic following as

1) Improved accuracy and rates. The M.I.T. set at Fort Munro has given average errors of 2 minutes with a *5* second period superimposed on a lag of 4 minutes per degree per second rate. it should be possible to eliminate the lag and then the accuracy would compare favourable with visual accuracy.

2) Saving of operators. One operator may be sufficient.

3) Elimination of the falling off in efficiency found with operators under battle conditions and due to fatigue.

4) Higher rates and accelerations may be possible than with operators.

5) Quickness in changing target and settling down on predictors.

AU the above advantages apply particularly to short range gunneiy.

The disadvantages were.

1) Some increased complexity.

2) Accurate machining of certain parts.

3) Difficulty of fitting to existing mountings.

4) Multiply targets at the same range might give difficulty.

Note 2. (Extract from Report by Dr. Skinner.)

PRELIMINARY REPORT ON TESTS ON SIIIPS USING 10 cm. WAVES - NOVEMBER~ DECEMIBER~, 1940.

The following tests were performed at Swanage by members of T.R.E. and subsequently by members of the Signals School, Portsmouth, who were temporarily attached here. The apparatus used was the GEC El 198 magnetron (9.1 cms.) as transmitter, and a crystal mixer with 45 M. c. IF. The transmitter power was nominally *5* KW, but the exact amount radiated is not exactly shown. Transmitting and receiving aerials were placed at the loci of paraboloidal mirrors, 3 ft. in diameter, giving a gain of about 500. These were mounted so that their axes could be pointed towards the ship, manually or otherwise. In a few experiments, flat cylindrical-parabolic mirrors with an aperture of 6 ft. x 9 ins, were used. The gain of these mirrors is about 250. we thought that the flat beam (narrow in a horizontal plane but about *15°* in a vertical plane) might be suitable for use on a ship, rolling in a rough sea. The alternative would be a complex system of gyro-stabilisation.

Three sets of radio-apparatus ‘re used - (a) and (b), of which (b) was an almost exact copy of (a). Apparatus (c) was also very similar, the main difference being that it was better engineered. The performances of the three sets of apparatus were not quite identical. This is unfortunately inevitable in the present early state of development of 10 cm. apparatus.

TEST 1. 7TH NOVEMBER 1940. APPARATUS (a) - Site Leeson House *(250* ft.) Sea fairly calm.

The “Titlark”, a boat of 92 tons and steel construction was followed end-on 107 nautical miles (Signal approximately 3 times noise). The boat began to return towards the apparatus; signals very clear, though fluctuating, the whole time.

TEST 2. 11TH NOVEMBER 1940. APPARATUS (b) - Site Leeson House (250 ft.) Sea fairly calm.

Submarine (U-class, the “Usk”) was seen up to about 7 V_2 nautical miles. Strong signals up 106 nautical miles. These figures apply to the stem-on view. The broadside-on view seemed to give signals about twice as strong. Horizontal polarisation of the source seemed slightly preferable to vertical polarisation. Between *4* and 4’/2 miles, the submarine dived and the signal disappeared. On coming to the surface, the signal re-appeared at a time when at most the periscope and

conning tower were visible. Signals at extreme range are always rather fluctuating, and at extreme range were liable to disappear for rather long intervals.

Note 3. (Extract from report by Dr. Varley).

Petersham Research Group Report No.13.

CD SETS AT DOVER

5. OPERATIONAL USE OF 271.

All plots are passed to the Naval Staff Room at Dover Castle. Most of the enemy shipping found in daylight close to the French coast. When the ships are not visible, and weather is good enough for flying, a Spitfire is sent out to identify the ship or ships. If a large ship if found, bombers are sent out Trawlers and Minesweepers are not normally attacked in this way, but the Spitfire will in these cases use its cannon. Few ships are allowed to pass through without attack.

Formerly Spitfires kept up a patrol off the enemy coast to detect shipping. This is no longer necessary and has been discontinued.

The Naval Staff gets so few plots from CD/CHL and 284 that they now rely almost entirely on 271 for their information.

During the past week the weather has often been bad for flying, and not all targets were identified. Details of identification will be included in a second report.

Three incidents require special mention. On August 10th, a
2,000-ton tanker was followed along the coast. It was attacked and hit by a bomb off Gravelines.

On the 7th August a friendly- eastbound convoy was picked up at 63,000 yards by 271. M. 1 detected it at 40,000 yards. The convoy was followed in by both sets. It later transpired that two torpedoes were fired at, but missed the convoy, although no plots had been passed on any enemy vessels.

On the night of August 10th - 11th, a westbound convoy passed by. Plots on the convoy were passed by CD/CHL and 284, but 271 was instructed to search for enemy vessels attempting interception. Plots were obtained on E. boats, which gave the convoy warning an hour or more before any attack was delivered. The Destroyer escort twice opened fire. Signals sent to our Motor Launched enabled them to alter course and intercept some E Boats, which were seen, but rough weather prevented our Launches from engaging the enemy. One ship of the convoy was sunk by a torpedo.

The Navy was highly satisfied with the performance of 271, and said that they could not have expected more from it They would like to have two more sets to cover the coastal area from the Downs to beyond Hastings.

Note 4. (Extract from report by Dr. Varley).

On Coastal Defence Sets at Dover

1

WEEK 26th - 31st AUGUST 1941

26th. Several trawlers and 30 barges were reported off Calais and E-boats and 8 small trawlers went from Calais to Boulogne. An attack by cannon-fighters on the barges and minesweepers left one burning well, and one with white smoke and one with black smoke issuing from it.

27th, 05.19 hrs. Three vessels left Boulgne; one of 2,000 tons with two escorts. An attempt at interception was frustrated by the ships entering Calais.

29th. The same ships were reported leaving Calais, and were plotted to 3 miles east of Gravelines (70,000 ids). An attack was planned, but the vessels entered Dunkirk.

30th A large Tanker was found off Gravelines and plotted into Calais.

Note 5. (Copy of Minute to E.S.3 (T)).

E.S.3 (T).

10cm C.D.

With reference to your minute RD/29/11157 of 9.4.41, we propose to take the following action:

1. To fit the Signal School set into the G.E transmitter cabin to enable trials to be carried out at different heights and upon different sites.

2. To add a 10-cm. mixer stage to the No.3 CD receiver and to use this set in conjunction with 10 cm. transmitter, which has already been built, and two six foot mirrors to be mounted on the roof of the CD building on the existing aerial mounting system. This set will later be mounted in the 3rd cabin, which was originally provided for the GL Mark III prototypes. Dr, Walmsley has agreed that this shall be allotted to A.D.RD.B. for this work.

Since we consider the ranges obtainable on surface vessels are now definitely established to be much superior to those obtainable with the 150 cm. CD set, we consider that the provision of 10 cm. sets for coast watching on low sites on the East Coast should be undertaken as a matter of urgency. We suggest that we construct a number, say 5, of these sets in the A.D.RD.E. workshops at once. We estimate delivery as follows:

No. 1 by end of July, Nos. 2 and 3 by end of August, Nos. 4 to 6 by end of September.

(sgd) J.D. Cockcroft,

Chief Superintendent, A.D.R.D.E.
Somerford,
Christchurch, Hants.
6.5.41.

Note 6. (Extract from Minute to D.D.S.E. (3)).

D.D.S.E. (3) (thro' E.S.3. (T))

Long Range 10-cm. Ship Detection Set.

In accordance with the recommendations of the R.D.F. Applications Committee at their meeting on 1.7.41. we are constructing a 10-cm. Ship Detection Set using a single 10-ft. mirror and high power transmitter.

We should like to erect this set at a high point in order to determine the ranges obtained, and consider that Ventnor would be a suitable position since it ought to be possible to cover the channel to Cherbourg.

We discussed this matter with Air Marshal Joubort. C-in-C, Coastal Command on his visit to A.D.R.D.E. on 10.4.41. He agreed to take up the matter with Air Ministry, and to initiate action for a building to be provided.

We consider that a standard C.D. building simplified by the omission of one room would be suitable.

If this project is approved, it would require the provision of 1 set of Adamsons Turning Gear: 1 - 271(X) Set: 1-P.P.I. and 1 Diesel.*

(sgd) J.D. Cockcroft,

Chief Superintendent, A.D.R.D.E.

Somerford,
Christchurch, Hants.
6Oct.41.
KC

Note 7. (Extract from A.5 Meeting on 21.7.41

July 19 1941

2. C.D. Mark IV (X) *3* cms.

Preliminary experiments at T.R.E. have shown that with present technique the following ranges can be obtained from a height of 200 ft.

TARGET

M.T.B. or Titlark 18,000 yds. 2:1 signal noise.

Trawler above 20,000 yds.

By the use of a wavelength of 3 cms. the angular resolution can be increased to about one degree using 6-ft. mirrors. If at the same time the pulse length is reduced to 1/3 microsecond the necessary basis for splash indication is obtained.

We accordingly recommend that this set should be designed with the following display:

(1) AP.P.I. Unit,
(2) A splash indicator based on angular scanning over an arc of - $2V_2$ degrees, and a range scan of -1000
Yards.
(3) The range unit of G.L. Mk- III.

NOTE 8 (Extract from RD.F. Aids to Field Forces.) July 12, 1941

C.P.RS.D.

R.D.F. Aids to Field Forces

We have had some informal discussion with A.O.R.G., T.R.E., S.A./A.C., and others on possible R.D.F. aids to Field Forces.

The following proposals seem to merit further investigation:

1. Location of position of Infantry during operations at night or in smoke.

We understood that under such conditions advanced companies are apt to go astray and that the higher formations do not get a continuous picture of the development of the battle.

It is suggested that front line troops might make their position by firing R.D.F. markers to be located in plan on an R.D.F.E not with P.P.I. display at some operations centre.

The R.D.F. marker might consist of a special Very pistol containing suitable wire or a special composition to give intense ionisation.

The R.D.F. set should preferably be a standard set such as the L.W.

An investigation of these possibilities would not require much effort and we should like to pursue.

2. Location and Direction of Air Support.

T.R.E. are considering, with the Tactical Air Force, the control of low flying Air Support aircraft by fitting aircraft with an I.F.F. set repeating back signals on a different frequency from the interrogator. In this way clutter difficulties disappear and the interrogator can be located on a hill, with consequent advantages in range.

The use of the L.W. set for interrogation and location is under consideration. It may be necessary to add split, and some co-operation by A.D.R.D.E. may be required.

This proposal links up with (1) in that the Air Support Control may require the information to be provided by
(1).

3. Location of head of column in an advance.

We understood that if the control described in (2) is operative it would be advantageous to have the position of our most advanced vehicles marked at the same station so that the ‘bomb line” can be accurately defined.

This could be done if these vehicles carried a Eureka Mk. III, a responder weighing about 26 lbs. Ranges of about 20 miles are obtainable if an approximate line of sight to the vehicle is obtainable.

4. Provision of night aids to Artillery Forward Observation Posts.

It would be possible to provide Artillery Observation Posts with an R.D.F. set which would detect movements of vehicles on roads and so enable fire to be accurately, opened at night.

Such as set would be either a high resolution set of the “Fall of Shot” type or a C.W. or Pulse Doppler set. Ranges of about 10,000 yards would be required.